

What is claimed:

1.      A method of forming a pattern of a functional material on a substrate comprising:  
5                    applying a first pattern of a first material to said substrate; and  
                     applying a second functional material to said substrate and said first material, wherein said first material, said second functional material, and said substrate interact to spontaneously form a second pattern of said second functional material on said substrate, to thereby form a pattern of a functional material a substrate.  
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2.      The method of claim 1, further comprising applying an additional pattern of an additional material to said substrate, to thereby form a multi-layered pattern of materials on said substrate.
- 15      3.      The method of claim 2, wherein said additional material is the same as said first material.
- 20      4.      The method of claim 2, wherein said additional material is the same as said second material.
- 25      5.      The method of claim 2, wherein said additional material is different from said first and second materials.
- 30      6.      The method of claim 2, wherein said additional pattern is different from said first pattern.
- 35      7.      The method of claim 2, wherein said additional pattern is different from said second pattern.
8.      The method of claim 3, wherein said additional pattern is orthogonal to said first pattern.
9.      The method of claim 8, wherein said additional pattern is a chessboard pattern.
10.     The method of claim 5, wherein said additional pattern of additional material overlays said first and second patterns, thereby creating a multi-layer composite material.

11. The method of claim 10, wherein said first and second materials are electrically conducting materials, thereby creating electrically conducting junctions.

5 12. The method of claim 1, wherein said second material is applied substantially uniformly to said substrate containing said first pattern.

13. The method of claim 1, wherein said second material comprises an information carrying material such that said second pattern possesses engineered  
10 functionality.

14. The method of claim 1, wherein said interaction among said first material, said second material, and said substrate is selected from the group of interactions consisting of hydrophobic/hydrophilic, solvent wettability, ionic forces,  
15 ion-dipole forces, hydrogen bonds, charge transfer forces, Van der Waals forces, chemical (covalent) bonds, general mechanical adhesion, penetration, and magnetic interactions.

15. The method of claim 14, wherein said interaction among said first  
20 material, said second material, and said substrate is hydrophobic/hydrophilic.

16. The method of claim 1, further comprising removing said first pattern of the first material from said substrate.

17. The method of claim 1, wherein said first pattern of the first material is applied by a method selected from the group consisting of non-contact printing, photolithographic printing, offset printing, silk-screen printing, stamping, etching, hand-drawing, and any combination thereof.

18. The method of claim 17, wherein said first pattern of the first material is applied by non-contact printing.

19. The method of claim 18, wherein said non-contact printing comprises electrophotographic printing.

20. The method of claim 18, wherein said first pattern of the first material is applied by laser printing.

21. The method of claim 18, wherein said first pattern of the first material is applied by xerographic printing.

22. The method of claim 18, wherein said first pattern of the first material is applied by solid ink printing.

23. The method of claims 20 or 21, wherein said first material comprises a toner ink.

24. The method of claim 18, wherein said first pattern of the first material has a line resolution of at least about 10  $\mu\text{m}$ .

25. The method of claim 1, wherein said second pattern is the same as said first pattern.

26. The method of claim 1, wherein said second pattern is the inverse of said first pattern.

27. The method of claim 1, wherein said substrate is selected from the group consisting of glass, metal, plastic, wood, fabric, paper, quartz, crystal, stone, and ceramic.

28. A method of forming a pattern of a functional material on a substrate comprising:

non-contact printing a first pattern of a first material on said substrate; and

applying a second functional material to said substrate and said first material, wherein said first material, said second material, and said substrate interact to spontaneously form a second pattern of said second functional material on said substrate, to thereby form a pattern of a functional material on a substrate.

29. The method of claim 28, wherein said interactions between said first material, said second material, and said substrate are hydrophobic/hydrophilic such that said first material, said second material, and said substrate interact to spontaneously form a second pattern of said second material on said substrate.

30. The method of claim 28, further comprising removing said first pattern of the first material from said substrate.

31. The method of claim 28, wherein said non-contact printing comprises electrophotographic printing.

32. The method of claim 28, wherein said first pattern of the first material is applied by laser printing.

33. The method of claim 28, wherein said first pattern of the first material is applied by xerographic printing.

34. The method of claim 28, wherein said first pattern of the first material is applied by solid ink printing.

35. The method of claims 32 or 33, wherein said first material comprises a toner ink.

36. The method of claim 28, wherein said first pattern of the first material has a line resolution of at least about 10  $\mu\text{m}$ .

37. The method of claim 28, wherein said second pattern is the inverse of said first pattern.

38. The method of claim 28, wherein said substrate is flexible.

39. The method of claim 28, wherein said flexible substrate is selected from the group consisting of paper, plastic, and fabric substrates.

40. The method of claim 28, wherein said second material comprises an electrically active material.

41. The method of claim 40, wherein said second material comprises an electrically conductive polymer.

42. The method of claim 41, wherein said second material comprises an aqueous mixture of an electrically conductive polymer.

43. The method of claim 28, wherein said first material has an electrical conductance that is lower than that of said second material.

44. The method of claim 28, wherein said first material is electrically nonconductive ink.

45. The method of claim 28, wherein said substrate has an electrical conductance that is lower than that of said second material.

46. The method of claim 28, wherein said second material is electrically non-conductive.

47. A method of forming a pattern of a functional material on a substrate comprising:

non-contact printing a first pattern of a first material on said substrate; and

applying a second functional material to said substrate and said first material, wherein said first and second functional materials are selected to have a sufficient difference in at least one property of hydrophobicity and hydrophilicity relative to one another such that said first material, said second functional material, and said substrate interact to spontaneously form a second pattern of said second functional material on said substrate, to thereby form on said substrate a second pattern of said second functional material, wherein said second pattern is the inverse of said first pattern, to thereby form a pattern of a functional material to a substrate.

48. The method of claim 47, further comprising removing said first pattern of the first material from said substrate.

49. The method of claim 47, wherein said non-contact printing comprises electrophotographic printing.

50. The method of claim 47, wherein said non-contact printing comprises laser printing.

51. The method of claim 47, wherein said non-contact printing comprises xerographic printing.

52.      The method of claim 47, wherein said first pattern of the first material is applied by solid ink printing.

53.      The method of claim 47, wherein said substrate is flexible.

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54.      The method of claims 50 or 51, wherein said first material comprises a toner ink.

55.      The method of claim 54, wherein said second material comprises an aqueous solution of an electrically conductive polymer.

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56.      The method of claim 55, wherein said substrate and said toner ink are electrically non-conducting relative to said electrically conductive polymer.

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57.      A method of forming an electrical circuit element, comprising:

applying a first pattern of a first material on a substrate; and

applying a second material to said substrate and said first material,

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wherein said first material, said second material, and said substrate interact to spontaneously form a second pattern of said second material on said substrate, thereby forming an electrical circuit element.

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58.      The method of claim 57, wherein said first pattern of the first material is applied by non-contact printing.

59.      The method of claim 57, wherein said non-contact printing comprises electrophotographic printing.

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60.      The method of claim 58, wherein said non-contact printing comprises laser printing.

61.      The method of claim 58, wherein said non-contact printing comprises xerographic printing.

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62.      The method of claim 58, wherein said solid ink printing.

63.      The method of claims 60 or 61, wherein said first material comprises a toner ink.

64.      The method of claim 58, wherein said first pattern of the first material has  
5      a line resolution of at least about 10  $\mu\text{m}$ .

65.      The method of claim 57, wherein said second pattern is the inverse of said first pattern.

10      66.      The method of claim 57, wherein said substrate is selected from the group consisting of glass, metal, plastic, wood, fabric, paper, quartz, crystal, stone, and ceramic.

15      67.      The method of claim 57, wherein said first and second materials are selected to have a sufficient difference in at least one property of hydrophobicity and hydrophilicity relative to one another such that said first material, said second material, and said substrate interact to spontaneously form a second pattern of said second material on said substrate.

20      68.      The method of claim 57, further comprising removing said first pattern of said first material.

69.      The method of claim 67, wherein said substrate is a flexible substrate.

25      70.      The method of claim 67, wherein said substrate is a flexible plastic substrate.

71.      The method of claim 70, wherein said first material is electrically non-conductive.

30      72.      The method of claim 71, wherein said first material is a toner ink.

73.      The method of claim 67, wherein said first material is a polyimide.

35      74.      The method of claim 72, wherein said second material is an electrically active material.

75. The method of claim 74, wherein said electrically active material is an electrically conductive material that is selected from the group consisting of polymeric material, a metallic dispersion, a metallic solution, a sol gel of indium tin oxide, a non-polymeric material, and a derivative thereof.

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76. The method of claim 75, wherein said polymeric material is selected from the group consisting of a polypyrrole, a polythiophene, a polyaniline, a polyphenylenevinylene, and a polyacetylene, and a derivative thereof.

10 77. The method of claim 76, wherein said polymer comprises poly-3,4-ethylenedioxythiophene-polystyrene sulfonate (PEDOT-PSS).

15 78. The method of claim 74, wherein said electrically conductive material comprises a non-polymer selected from the group consisting of a phthalocyanine, a porphyrin, an anthracene, a fullerene, a triphenylamine, a stilbene, and a derivative thereof.

20 79. The method of claim 57, wherein said second material is applied substantially uniformly to said substrate containing said first pattern.

80. The method of claim 79, wherein said second material is applied by rolling the second material onto the substrate, spraying the second material onto the substrate, melting the second material onto the substrate, dipping the substrate into the second material, or exposing the substrate to gasses or vapors of the second material.

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81. The method of claim 79, further comprising applying a third material by rolling the third material onto the substrate, spraying the third material onto the substrate, melting the third material onto the substrate, dipping the substrate into the third material, or exposing the substrate to gasses or vapors of the third material, wherein the combination of the second and third material produces a functionally active fourth material.

30 82. The method of claim 68, wherein said first material is removed by ultrasonic treatment with a solvent, cleaning with a solvent, cleaning by mechanical action, adhesive modification through chemical alteration, evaporation or melting.

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83. The method of claim 57, wherein said circuit element is selected from the group consisting of an inductor, a resistor, a capacitor, an Inductor-Capacitor (LC) resonator, a switch, a filter, a transistor, a Schottky junction, a p-n junction, and a sensor.

5 84. The method of claim 57, wherein said circuit element is an inductor.

85. The method of claim 57, wherein said circuit element is a resistor.

86. The method of claim 57, wherein said circuit element is a capacitor.

10 87. The method of claim 57, wherein said circuit element is an Inductor-Capacitor (LC) resonator.

88. The method of claim 57, wherein said circuit element is a switch.

15 89. The method of claim 57, wherein said circuit element is a filter.

90. The method of claim 57, wherein said circuit element is a transistor.

20 91. The method of claim 57, wherein said circuit element is a Schottky junction.

92. The method of claim 57, wherein said circuit element is a p-n junction.

25 93. The method of claim 57, wherein said circuit element is a sensor.

94. The method of claim 57, wherein said circuit element is an electric stress sensor.

30 95. The method of claim 83, wherein said circuit element comprises an inductor and said second pattern comprises at least one of a serpentine pattern and a spiral pattern.

35 96. The method of claim 83, wherein said circuit element comprises a resistor defined by the length, width, and height of said second pattern and the conductivity of said second material.

97. The method of claim 83, wherein said circuit element comprises a capacitor, wherein the first material is a dielectric and the second material is an electrically conductive material that further comprises an interdigitated pattern of said first and said second materials on said substrate to thereby form a pattern of said electrically conductive second material on said substrate separated by a dielectric.

98. The method of claim 97, further comprising removing said first pattern of first material from said substrate, thereby providing a capacitor comprised of a pattern of said electrically conductive second material on said substrate, wherein air is said dielectric.

99. The method of claim 83, wherein said circuit element comprises a capacitor, wherein said pattern of said first material is applied to both sides of said substrate and said second material is applied to said patterns of said first material on said substrate, wherein said second pattern forms on both sides of said substrate, such that said second material is electrically conductive and said second patterns overlap, at least in part, to thereby form two patterns of said electrically conductive second material on said substrate separated by said dielectric substrate.

100. The method of claim 83, wherein said circuit element further comprises a second circuit element, wherein said second circuit element is formed by: non-contact printing a third pattern of a third material on a second substrate; and applying a fourth material to said second substrate and said third material; wherein said third material, said fourth material, and said substrate interact to spontaneously form a second pattern of said fourth material on said substrate, wherein the second material and fourth material on said first and said second substrates comprise an electrically conductive material, and said pattern of said first substrate and said pattern of said second substrate are opposed to each other so as to form a switch in which the electrically conductive material on each substrate is separated by the respective heights on the substrates of the first material and the third material until at least one of the substrates is depressed so as to put the electrically conductive materials into electrical contact with each other.

101. The method of claim 100, wherein said first and third materials are the same.

102. The method of claim 83, wherein said filter is a Resistor-Capacitor (RC) filter.

103.    The method of claim 90, wherein said filter comprises a first pattern of electrically conductive material connected to electrical ground and a second pattern of electrically conductive material connected to an input signal at one end of said second pattern and to an output at another end of said second pattern, said circuit further comprising at least one capacitor electrically connected between said first and second patterns to form an RC filter.

104.    The method of claim 83, wherein said transistor is a field effect transistor-like device.

105.    The method of claim 104, wherein said electrically conductive material comprises a semi-conducting polymer material deposited on said substrate as at least one of a source, a drain, and a connection between said source and drain.

106.    The method of claim 105, further comprising applying said semi-conducting polymer material as a control layer forming a gate disposed over said electrically conductive polymer material connecting said source and said drain and separated therefrom by an insulator.

107.    The method of claim 105, wherein said semi-conducting polymer material is selected from the group consisting of a phthalocyanine, a porphyrin, an anthracene, a fullerene, a triphenylamine, a stilbene, and a derivative thereof.

108.    The method of claim 72, further comprising removing said first pattern of toner ink by ultrasound treatment with an organic solvent.

109.    An electrical circuit element prepared by the method of any one of claims 57, 67, or 68.

110.    An electrical circuit element comprising:

a substrate;

a first pattern of an insulating material applied to said substrate; and

a second pattern of an electrically conducting material applied to said substrate and said first material, wherein said insulating material, electrically conducting

material, and said substrate interact to spontaneously form a second pattern of said electrically conducting material on said substrate when said electrically conducting material is applied to said substrate having said first pattern of said insulating material applied thereon.

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111. The electrical circuit element of claim 110, wherein said first pattern of the first material is applied by a method selected from the group consisting of non-contact printing, photolithographic printing, offset printing, silk-screen printing, stamping, etching, hand-drawing, and any combination thereof.

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112. The electrical circuit element of claim 111, wherein said first pattern of the first material is applied by non-contact printing.

113. The electrical circuit element of claim 111, wherein said non-contact printing comprises electrophotographic printing.

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114. The electrical circuit element of claim 112, wherein said non-contact printing comprises laser printing.

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115. The electrical circuit element of claim 112, wherein non-contact printing comprises xerographic printing.

116. The electrical circuit element of claim 112, wherein said first pattern of the first material is applied by solid ink printing.

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117. The electrical circuit element of claims 114 or 115, wherein said first material comprises a toner ink.

118. The electrical circuit element of claim 112, wherein said first pattern of the first material has a line resolution of at least about 10  $\mu\text{m}$ .

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119. The electrical circuit element of claim 110, wherein said substrate is selected from the group consisting of glass, metal, plastic, wood, fabric, paper, quartz, crystal, stone, and ceramic.

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120. The electrical circuit element of claim 110, wherein said first pattern is removed from said substrate.

121. The electrical circuit element of claim 110, wherein said electrically conducting material comprises poly-3,4-ethylenedioxythiophene-polystyrene sulfonate (PEDOT-PSS).

5 122. The electrical circuit element of claim 110, wherein said second pattern is the inverse of said first pattern.

123. An electronic device comprising:

- 10 a) a first circuit element comprising
- i) a first substrate;
  - ii) a first pattern of an insulating material applied to said substrate
- and
- 15 iii) a second pattern of an electrically conducting material applied to said substrate and said first material, wherein said insulating material, electrically conducting material, and said substrate interact to spontaneously form a second pattern of said electrically conducting material on said substrate when said electrically conducting material is applied to said substrate having said first pattern of said insulating material applied thereon;
- 20 b) a second circuit element comprising
- i) a second substrate;
  - ii) a third pattern of an insulating material applied to said second substrate and
- 25 iii) a fourth pattern of an electrically conducting material applied to said second substrate and said third material, wherein said insulating material, electrically conducting material, and said second substrate interact to spontaneously form a fourth pattern of said electrically conducting material on said substrate when said electrically conducting material is applied to said substrate having said third pattern of
- 30 said insulating material applied thereon; and
- c) an electrical connection between said first and second circuit elements.

124. The electronic device of claim 123, wherein said electrical connection is  
35 provided by a fastener selected from the group consisting of a rivet, a grommet, a metal staple, a coated metal staple, a metal wire, a snap, and a coated metal wire.

125.    The electronic device of claim 124, wherein said electrical connection is a grommet.

126.    The electronic device of claim 124, wherein said electrical connection is  
5    a metal wire.

127.    A Radio Frequency (RF) tag comprising a pattern of a nonconductive first material on a substrate and a coating of an electrically conductive second material disposed over said substrate and said first material, wherein said first material, said  
10    second material, and said substrate interact to spontaneously form a second pattern of said second material on said substrate, to thereby form an Inductor-Capacitor (LC) resonator on said substrate.

128.    The RF tag of claim 127, wherein said first pattern of the first material is  
15    applied by a method selected from the group consisting of non-contact printing, photolithographic printing, offset printing, silk-screen printing, stamping, etching, hand-drawing, and any combination thereof.

129.    The RF tag of claim 128, wherein said first pattern of the first material is  
20    applied by non-contact printing.

130.    The RF tag of claim 128, wherein said non-contact printing comprises electrophotographic printing.

131.    The RF tag of claim 128, wherein non-contact printing comprises laser  
25    printing.

132.    The RF tag of claim 128, wherein non-contact printing comprises  
30    xerographic printing.

133.    The RF tag of claim 128, wherein said first pattern of the first material is applied by solid ink printing.

134.    The RF tag of claims 131 or 132, wherein said first material comprises a  
35    toner ink.

135.    The RF tag of claim 128, wherein said first pattern of the first material has a line resolution of at least about 10  $\mu\text{m}$ .

136.    The RF tag of claim 127, wherein said second pattern is the inverse of said first pattern.

5            137.    The RF tag of claim 127, wherein said substrate is selected from the group consisting of glass, metal, plastic, wood, fabric, paper, quartz, crystal, stone, and ceramic.

138.    The RF tag of claim 127, wherein said electrically conductive material  
10 and said pattern of said first material together form a capacitor and an inductor on a same side of said substrate.

139.    The RF tag of claim 127, wherein said electrically conductive material  
and said pattern of said first material together form a capacitor and an inductor on  
15 respective sides of said substrate that are connected to one another through the substrate.

140.    The RF tag of claim 127, wherein said first material and said substrate  
being selected to have sufficient differences in at least one of hydrophobicity and  
hydrophilicity relative to said electrically conductive second material.  
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141.    An mechanical device comprising:

a)      a first component comprising  
          i) a first substrate;  
25           ii) a first pattern of first material applied to said first substrate and  
          iii) a second pattern of material applied to said first substrate and  
said first material, wherein said second pattern of said second material is spontaneously  
formed by the interaction of said first material, said second material and said first  
substrate; and  
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b)      a second component comprising  
          i) a second substrate;  
          ii) a third pattern of a third material applied to said  
second substrate and  
35           iii) a fourth pattern of fourth material applied to said second  
substrate and said third material, wherein said fourth pattern of said fourth material is  
spontaneously formed by the interaction of said third material, said fourth material and  
said substrate; and

wherein said first and second components are oriented in a such a way that the second and fourth patterns oppose each other, and are selected from the group consisting of identical patterns, inverse patterns, and any mechanically useful combinations.

5           142.   The mechanical device of claim 141, wherein said first and third patterns of said first and third materials are applied by a method selected from the group consisting of non-contact printing, photolithographic printing, offset printing, silk-screen printing, stamping, etching said substrate with ink, hand-drawing, and any combination thereof.

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          143.   The mechanical device of claim 142, wherein said first and third patterns of said first and third materials are applied by non-contact printing.

15           144.   The mechanical device of claim 142, wherein said non-contact printing comprises electrophotographic printing.

          145.   The mechanical device of claim 143, wherein said non-contact printing comprises laser printing.

20           146.   The mechanical device of claim 143, wherein said non-contact printing comprises xerographic printing.

          147.   The mechanical device of claim 143, wherein said non-contact printing comprises solid ink printing.

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          148.   The mechanical device of claims 145 or 146, wherein said first and third materials comprise a toner ink.

30           149.   The mechanical device of claim 143, wherein the first and third patterns of the first and third materials have a line resolution of at least about 10  $\mu\text{m}$ .

          150.   The mechanical device of claim 141, wherein said first and second substrates are selected from the group consisting of glass, metal, plastic, wood, fabric, paper, quartz, crystal, stone, and ceramic.

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          151.   The mechanical device of claim 141 selected from the group consisting of a micro-fluidic channel, a seal, a snap-in fittings, a keypad, and a touch-pad.



152. The mechanical device of claim 151 comprising a micro-fluidic channel.

153. The mechanical device of claim 151 comprising a seal.

5 154. The mechanical device of claim 151 comprising a snap-in fitting.

155. The mechanical device of claim 151 comprising a touch-pad.

156. The mechanical device of claim 151 comprising a keypad.

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157. A mechanical device prepared by the method of any one of claims 1, 28 or 47.

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